RETURN TO
ENVIRONMENTAL TEST
76-18 B/104

eems File System
electronic engineers service
Sec. 4000

3A22

POWER SUPPLIES UNLIMITED

NJE CORPORATION Kenilworth, New Jersey

Digitized by the Internet Archive
in 2025

https://archive.org/details/manualsplus_08182

INSTRUCTION MANUAL
FOR

CR-LINE

TRANSISTORIZED REGULATED

POWER SUPPLY

NJE CORPORATION
20 Boright Avenue
Kenilworth, New Jersey
Tel: (201) BRidge 2-6000
TWX: Cranford 51
Telefax: FFP

8000210

TABLE OF CONTENTS

Section	Title	Page
I	Specification and Description.....	1-1
II	Installation and Operation.....	2-1
	2-1 Unpacking	2-1
	2-2 Installation	2-1
	2-3 Connections and Controls	2-1
	2-4 Operation	2-4
III	Principles of Operation.....	3-1
	3-1 General	3-1
	3-2 Detailed Circuit Description	3-1
IV	Maintenance.....	4-1
	4-1 General	4-1
	4-2 Spare Modules	4-1
	4-3 Malfunctions	4-1
	4-4 No Output Voltage at Any Control Setting	4-2
	4-5 Low Output Voltage Relative to Voltage Adjust Setting	4-4
	4-6 High Output Voltage	4-4
	4-7 Failure to Regulate	4-5
	4-8 Poor Regulation	4-6
	4-9 Excessive Ripple	4-6
	4-10 Instability	4-7
	4-11 Inadequate Transient Response	4-8
	4-12 Oscillation	4-9
	4-13 Regulation Check	4-10
	4-16 Feedback Amplifier Check	4-11

SECTION I
SPECIFICATIONS AND DESCRIPTION

1-1. SPECIFICATIONS

Input:

Model	Volts	Line Current	Power Factor
CR 18-30	105-125 55-65 CPS	10 A	0.7
CR 36-8	105-125 55-65CPS	5.6A	0.7
CR 36-15	105-125 55-65CPS	11A	0.7
CR 36-20	105-125 55-65CPS	15A	0.7
CR 36-30	105-125 55-65CPS	19A	0.7
CR 60-9	105-125 55-65CPS	11A	0.7
CR 60-18	105-125 55-65CPS	21A	0.7

Output: Continuously adjustable by a front panel tenturn potentiometer.

Model	Volts	Amperes	Resolution
CR 18-30	0-18	0-30	3MV
CR 36-8	0-36	0-8	5MV
CR 36-15	0-36	0-15	5MV
CR 36-20	0-36	0-20	5MV
CR 36-30	0-36	0-30	5MV
CR 60-9	0-60	0-9	7MV
CR 60-18	0-60	0-18	7MV

Polarity: The output can be floated up to 500 volts peak above or below ground. Either polarity may be grounded to chassis.

Ripple: Total hum and noise will not exceed 1 millivolts rms.

Load Regulation:

Model	Static Load Regulation, No Load to Full Load.
CR 18-30	±0.01% or ±1MV *
CR 36-8	±0.01% or ±1MV *
CR 36-15	±0.01% or ±1MV *
CR 36-20	±0.01% or ±1MV *
CR 36-30	±0.01% or ±1MV *
CR 60-9	±0.01% or ±1MV *
CR 60-18	±0.01% or ±1MV *

* Whichever is greater

Recovery Time: The output voltage will remain within the regulated region for instantaneous, prolonged steps of the line voltage of ±10V. The recovery time for a no load to full load step change (or full load to no load) will not exceed 25 microseconds.

Derating: These supplies are rated for continuous duty over a temperature range from 0° C to 45° C. For service in higher ambient temperatures, the current rating must be reduced linearly to zero current at 80° C.

Termination: A barrier type terminal strip at the rear of the unit provides terminals for input, output, remote sensing, remote programming, dualling, and ground.

Series Parallel (Dualling Operation: Two or more similar units may be operated in series to provide higher voltages at rated current, or in parallel to provide higher currents at rated voltage.

Circuitry: Completely solid state. Silicon power rectifiers, silicon zener diode reference, germanium control and power transistors, all well-derated, characterize the quality and dependability of this supply.

Special Notes: Model CR 36-8 is convection-cooled, high efficiency heatsink eliminates the need for blowers. Models CR 18-30, CR 36-15, CR 36-20, CR 36-30, CR 60-9 and CR 60-18 are forced air-cooled by means of internal blowers. Do not block air flow.

Stability: ±0.05% or 2MV for 24-hour day at laboratory conditions.

Protection: Load and power supply protection for momentary overload or short circuit conditions is accomplished by an electronic current limiting circuit.

If the fault condition is sustained, automatic removal of the load is effected by the thermal characteristics of a slow-blow type fuse.

Remote Sensing: Sensing terminals, separate from the output terminals, are provided in order that the unit may "sense", and regulate against, the voltage at the load rather than the voltage at the output terminals.

Remote Programming: This circuit has a sensitivity of about 140 ohms per volt. "Remote Program" terminals are provided. By varying the remote resistance in series with these two terminals, the output voltage may be accurately controlled from zero to rated voltage.

Meters: Two rectangular 2% meters are furnished installed on the front panel.

Model	Ammeter Range	Voltmeter Range	Meter Size
CR 18-30	0-30A	0-20V	3-1/2
CR 36-8	0-10A	0-40V	3-1/2
CR 36-15	0-20A	0-40V	3-1/2
CR 36-20	0-20A	0-40V	3-1/2
CR 36-30	0-30A	0-40V	3-1/2
CR 60-9	0-10A	0-80V	3-1/2
CR 60-18	0-20A	0-80V	3-1/2

Physical Data:

Model	H In.	W In.	D In.	Net Weight	Shipping Weight
CR 18-30	7	19	16-5/8		105
CR 36-8	3-1/2	19	16-5/8		75
CR 36-15	5-1/4	19	16-5/8		90
CR 36-20	7	19	16-5/8		105
CR 36-30	8-3/4	19	16-5/8		120
CR 60-9	5-1/4	19	16-5/8		90
CR 60-18	8-3/4	19	16-5/8		120

Mounting: Suitable for laboratory bench use, or for 19" rack mounting.

Finish: Panel finish is two-tone gray enamel.

Panel Elements:
"On-Off" switch
AC line fuse in extractor post
"On" pilot light (red)
Output voltage control knob
Output ammeter
Output voltmeter

Environmental Conditions: This power supply will operate satisfactorily over the entire temperature range from +50°F to +120°F, with humidity up to 90% at altitudes up to 10,000 feet, without derating.

1-2 The power supply chassis assembly has an over-all width of 17 inches, and is mounted on a standard 19-inch relay rack panel. Components are mounted on sub-chassis which are secured between two side frames. This construction permits a free flow of air among the components, to facilitate dissipation of heat by the internal forced air-cooling and/ or by convection radiation.

1-3 The unit is designed for installation in a standard relay rack or cabinet as well as for use as a bench instrument. It is equipped with a perforated metal cover which serves to protect both equipment and user during operation. All input, output, and control connections are available on a barrier-type terminal strip at the rear of the unit; and include two chassis ground connections, and the following terminals:

1. AC input
2. AC input
3. Remote control
4. Remote control
5. Dualling
6 Dualling
7. Positive sensing
8. Positive output
9. Positive capacitor
10. Negative capacitor
11. Negative output
12. Negative sensing

1-4. The front panel elements consist of rectangular output voltmeter and ammeter of 2% accuracy, and AC on-off switch, output voltage adjust, a red pilot lamp to indicate application of AC input power, and AC input fuse. The DC output circuit fuse (where provided) is mounted on the rear of the chassis alongside the terminal strip.

SECTION II

INSTALLATION AND OPERATION

2-1. UNPACKING. The power supply is shipped in a cardboard carton which is floated on sufficient insulation in a heavy-duty shipping carton. Aside from normal precaution against damage to the unit in opening the cartons and removing the unit, no special procedures are required. The literature packed with the supply should be removed and held for reference in operating the equipment.

2-2. INSTALLATION. The supply can be mounted in any convenient location for bench use, and requires no adjustment or modification for such application. If the unit is to be installed in a housing, it is recommended that the rack or cabinet used be equipped with angle brackets, shelves, or slides to receive the unit, rather than suspending the assembly by its front panel mounting screws. The panel is notched for standard rack mounting.

2-3. CONNECTIONS AND CONTROLS.

CAUTION!!

This unit is equipped with separate output-sensing terminals, which have been jumpered directly to the Output terminals of the supply. If regulation of the voltage at the remote load is desired, the jumperes must be removed and the sensing terminals must be connected directly to the remote load terminals. (observing polarity) by means of separate shielded leads. DO NOT OPERATE SUPPLY WITH SENSING LEADS UNCONNECTED.

When the unit has been properly placed in position, or mounted in its rack and secured in place by the panel screws, make the following connections:

1. Using No. 14AWG wire, connect either the positive (TB1-8) or negative (TB1-11) DC output terminals of the supply (depending upon desired output polarity) directly to the chassis ground terminal at the barrier strip on the rear of the chassis, and connect the ground terminal to the system ground. If it is necessary that the power supply circuit float above or below ground, the output terminal should be connected to the chassis ground terminal by a 0.1 microfarad, 600 W VDC capacitor in place of the direct connection. Use of this by-pass capacitor will improve the stability of the circuit in the ungrounded condition, and reduce the effect of external interference and hum.

2. Connect the positive and negative output terminals, (TB1-8) and (TB1-11), respectively, to the corresponding terminals of the external load, using no 8 AWG wire.

3. See Caution Note, Paragraph 2.3- Connect the positive sensing terminal (TB1-7) to the positive terminal of the remote load, and the negative sensing terminal (TB1-12) to the negative terminal of the remote load. A twisted pair of No. 20 AWG or larger wire should be used for these connections. If accurate regulation at the remote load is not essential, then the sensing leads may be connected directly at the power supply output terminals, i.e. jumper (TB1-7) and (TB1-8), and jumper (TB1-11) and (TB1-12).

4. Output Capacitor Connections. The power supply has been shipped from the factory with the POS CAP terminals (TB1-9) jumpered to POS OUT terminal (TB1-8) and NEG CAP terminal (TB1-10) jumpered to NEG OUT terminal (TB1-11). This connection is satisfactory for most applications. However, if improved transient and dynamic characteristics are required, the POS CAP and NEG CAP terminals should be connected to the remote load on separate, heavy-duty leads. Further improvement can be effected by using an independent capacitor (available from the factory) mounted physically as close to the ultimate load as is practical. Consult the NJE Engineering Department on special transient problems.

5. Remote Control-Programming. Terminals (TB1-3) and (TB1-4) are provided for the insertion in series of a remote control programming resistor. This circuit has a sensitivity of about 140 ohms per volt. When the panel voltage adjustment is set to zero, the output voltage may be accurately controlled from zero to rated voltage by varying the remote resistance.

6. Dualling. Two supplies may be operated in parallel (with an overall current derating of 10%), or in series. Consult the Dualling Schematic Figure I for proper interconnection and wiring of the individual supplies and the load.

7. Connect the deactivated input line (115 volts nominal, 60 cycles, single phase) to the AC input terminals (TB1-1) and (TB1-2) on the barrier strip, using No. 10 AWG wire.

8. Fuse (AG) is located on the rear surface of the power supply.

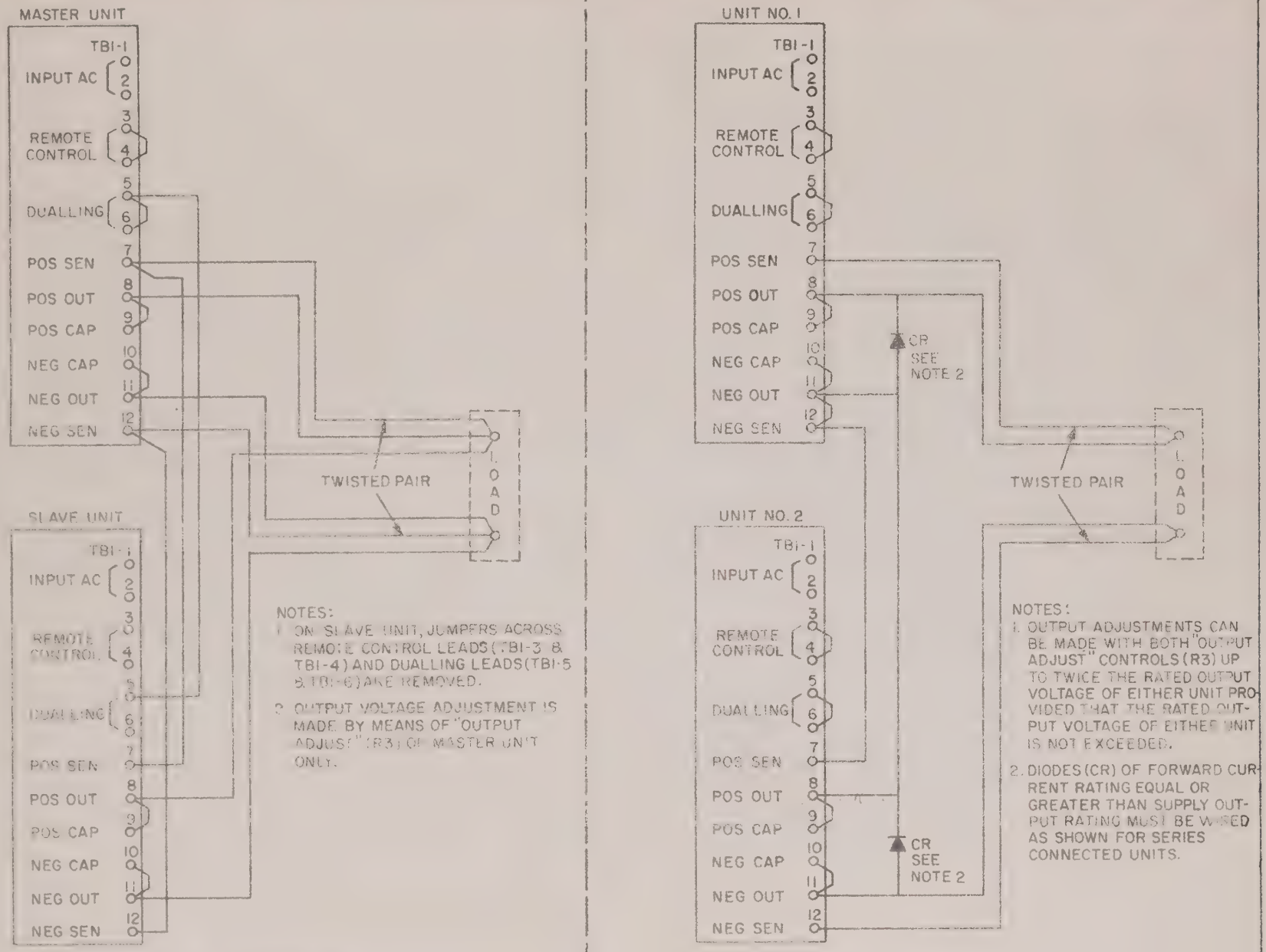
9. The overload current adjust potentiometer (AF) is located on the front panel.

10. The ON-OFF switch with the panel light indicators is located on the front panel.

11. The output voltage control knob is on the front panel.

12. The voltage and current indicating meters are on the front panel.

13. The terminal strip located in the rear of the unit contains terminations for input voltage, output, remote sensing, remote programming, dualling and ground.


MASTER UNIT
TBI-1
INPUT AC
REMOTE CONTROL
DUALLING
POS SEN
POS OUT
POS CAP
NEG CAP
NEG OUT
NEG SEN
TWISTED PAIR
LOAD
SLAVE UNIT
NOTES:
1. ON SLAVE UNIT, JUMPERS ACROSS REMOTE CONTROL LEADS (TBI-3 & TBI-4) AND DUALLING LEADS (TBI-5 & TBI-6) ARE REMOVED.
2. OUTPUT VOLTAGE ADJUSTMENT IS MADE BY MEANS OF "OUTPUT ADJUST" (R3) OF MASTER UNIT ONLY.
PARALLEL CONNECTION
UNIT NO. 1
UNIT NO. 2
CR
SEE NOTE 2
NOTES:
1. OUTPUT ADJUSTMENTS CAN BE MADE WITH BOTH "OUTPUT ADJUST" CONTROLS (R3) UP TO TWICE THE RATED OUTPUT VOLTAGE OF EITHER UNIT PROVIDED THAT THE RATED OUTPUT VOLTAGE OF EITHER UNIT IS NOT EXCEEDED.
2. DIODES (CR) OF FORWARD CURRENT RATING EQUAL OR GREATER THAN SUPPLY OUTPUT RATING MUST BE WIRED AS SHOWN FOR SERIES CONNECTED UNITS.
SERIES CONNECTION

DUALLING SCHEMATIC
CR SERIES
FIGURE 1

101626

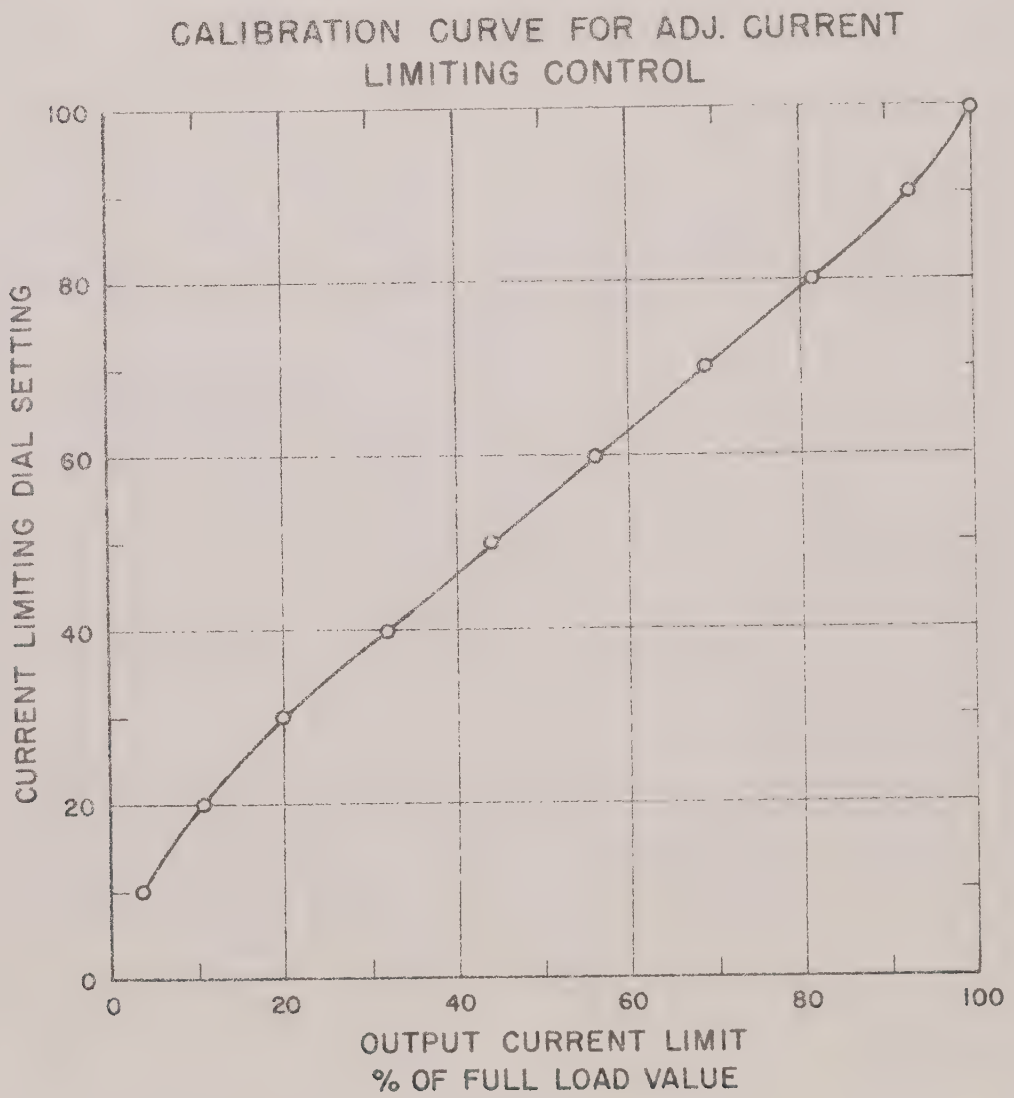
2-4 OPERATION

PLEASE NOTE!!

Pre-Load information, if required, is indicated on schematic which is located at the rear of this manual.

Set the AC Control switch in OFF (open) position and energize the AC input line. Set the OUTPUT ADJUST control to full counterclockwise position, then place the AC control switch in the ON position. The indicator on the front panel should light. Observing the panel voltmeter, adjust the load voltage to the desired value, by means of the OUTPUT ADJUST. Check the load current meter to avoid overload conditions. If the required voltage value cannot be achieved, de-energize the input line and check connections on the rear terminal strip before referring to the troubleshooting section of this manual. To use the Variable Current Adjust feature, set the front panel Current Adjust potentiometer to the current desired by means of calibration curve (Fig. A) or as follows: Load the power supply to the desired current at which limiting is required, then back off Current Adjust potentiometer until output voltage starts to fall off, rotate current adjust potentiometer a few degrees clockwise. Variable Current Adjust is accomplished by means of circuitry of A3 and current Adjust potentiometer (AF).

FIG. A


CALIBRATION CURVE FOR ADJ. CURRENT LIMITING CONTROL
CURRENT LIMITING DIAL SETTING
0
20
40
60
80
100
OUTPUT CURRENT LIMIT
% OF FULL LOAD VALUE

100830

SECTION III

PRINCIPLES OF OPERATION

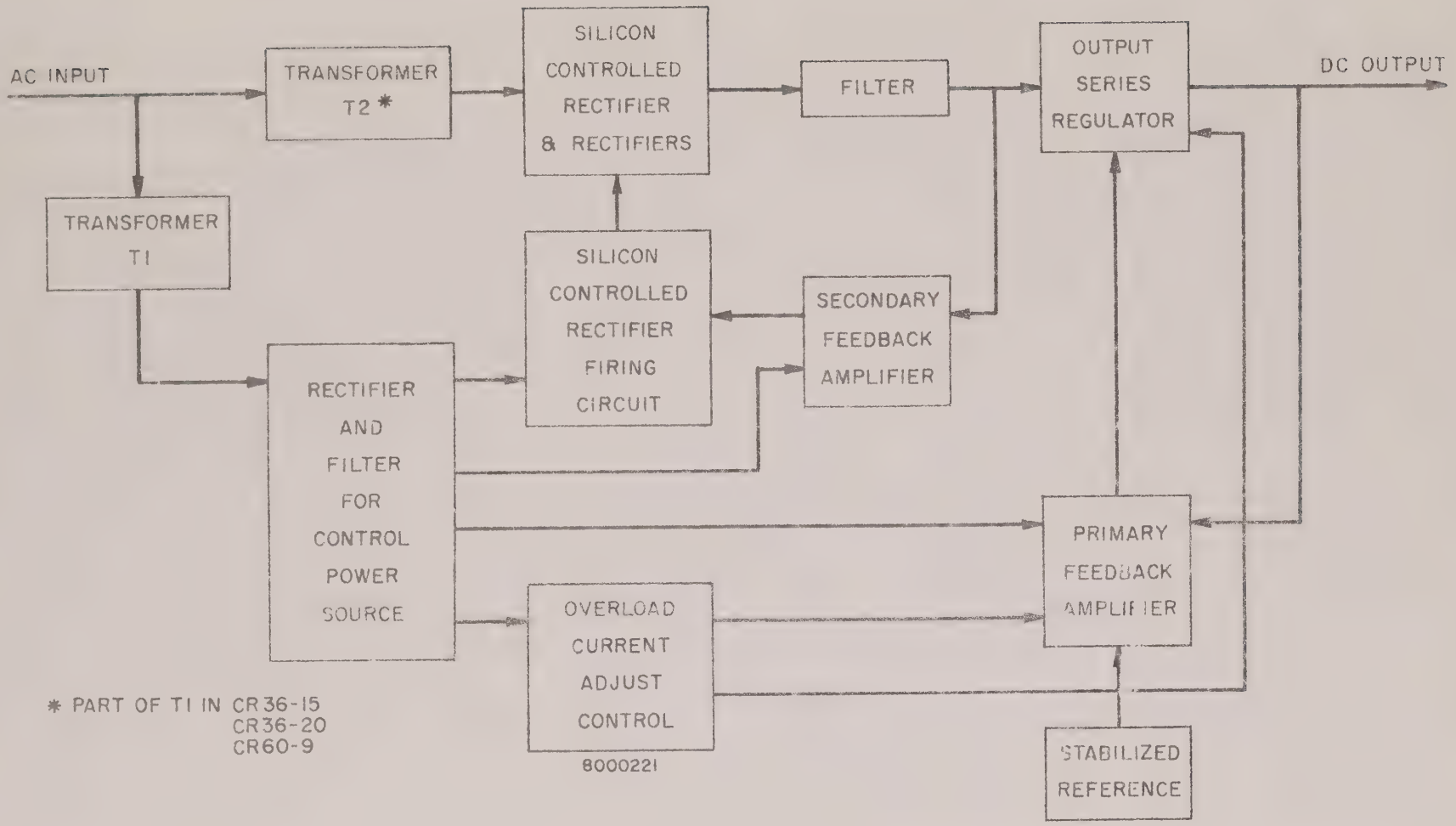
3-1 GENERAL. A simplified block diagram illustrating the basic elements of the circuit and the signal flow, is shown in Figure 2. The AC line voltage is transferred to adequate values to supply the Output Rectifiers and CR through transformers (T2) and for the firing circuit and transistor amplifier voltages through transformer (T1) and an associated AC to DC conversion. The average value of the signal from the CR is filtered by a capacitor input filter. The control of the average voltage to the series regulator is accomplished by control of the firing point of the CR, and will be discussed later. The output voltage furnished to the load by the series regulator is monitored by a feedback amplifier which compares this voltage with a stabilized reference voltage and amplifies the difference between the two voltages. The output of the amplifier is used to control the regulator in such a way that it counteracts any change in the DC output voltage, thereby furnishing an essentially constant voltage to the external load. The controlled rectifier is basically a device which controls the magnitude of average DC voltage at the capacitor input filter in such a way as to maintain the storage voltage across the series regulator within its dissipation capabiltiy.

3-2. DETAILED CIRCUIT DESCRIPTION. Circuit references in the following material apply to the schematic diagram at the back of the manual. This diagram shows electrical relationships, and is laid out in an arrangement approximately the same as that in the Block Diagram, Figure 2

3-3. The power supply is energized by connecting 115 volts (nominal), 60 cycles, single-phase, to the input terminals, and closing switch (S1), attested by the lighting of pilot lamp (DS1).

3-4. The power transformer winding (S) converts the 115 V AC input line to an appropriate value which is rectified to a pulsating DC output. This DC voltage is then filtered by capacitor (C1), and applied through a regulating transistor assembly (A) to the external load. Capacitor (B) provides additional filtering of the output, and reduces the internal impedance of the supply for high-frequency load variations.

3-5. The output voltage on the auxiliary winding (W) is rectified by diodes (CR101 and CR102) and (CR103 and CR104), and filtered by capacitor input filter (C102)- (C103) to provide positive and negative operating potentials for the feedback amplifier. Zener diode (CR109) in conjunction with its load resistor (C) provides regulated +18 V DC, while diode (CR110) with resistor (D) provides -18 V DC (measured with respect to the neutral bus of the amplifier). These zener diodes function in a manner analogous to that of a gaseous voltage regulator tube, providing a relatively constant output voltage across their terminals despite variations in the conducted current. Winding of (U) feeds (A2) the controlled rectifier power supply and driver circuit. The function of this circuit will be described later.



* PART OF T1 IN CR36-15
CR36-20
CR60-9

SIMPLIFIED BLOCK DIAGRAM

CR SERIES

FIGURE 2

101639

3-6. The feedback amplifier consists of three stages of amplification; the first two of which are balanced amplifiers, assuring minimum sensitivity to fluctuations in ambient temperature or operating voltages. The input signal of the output of the supply. This divider consists of resistors (E) and (F) in the amplifier, and resistor (G) on the main chassis. The resistance setting of (G) determines the operating value of the DC output voltage of the supply in a manner which will be explained below. Resistor (G) is the output voltage control knob on the front panel. (F101) at the base of (Q108) provides protection for both the precision feedback resistor (G) as well as the transistor during surges arising because of transient load conditions.

3-7. The negative end of the sensing voltage divider (negative end of resistor) (E) is returned to the negative output of the supply through zener diodes (CR111) and the negative sensing lead. The diode, in conjunction with its load resistor (H) provides a highly stable potential of 6 VDC for use as a comparison voltage by the input stage (Q107, Q108) of the feedback amplifier. When the output of the power supply (measured at the load) is precisely at its selected nominal value, the voltage at the base of transistor (Q108) (derived from the sensing voltage divider) is at the same level as the base of transistor (Q107), and the input stage is in balance. Under this condition, any tendency of the load voltage to vary in either direction will unbalance the amplifier, resulting in corrective action which compensates for the impending change, and holds the load voltage at its established value, as explained below.

3-8. Transistors (Q107) and (Q108) are PNP type units, operated in common-emitter mode, and connected as a balanced differential amplifier. Their outputs, taken across load resistors (I) and (J) are direct-coupled to the bases of the succeeding differential amplifier stage (Q105)-(Q106), which consists of two NPN transistors operated in common-emitter mode. The output of (Q105), from its load resistor (AD), drives the base of the single-ended output stage (Q104). The output of the amplifier is tied directly to the base of the driver transistor (Q101).

3-9. Regulation of the DC output is performed by a double regulating system. A transistor series regulator consisting of power transistors (A), operating in parallel, provides high-speed regulating action to correct for ripple and transient variations both at its input (AE-AB) and at the output of the supply. The amplifier loop which provides correction signals to the series regulator is driven directly from the output through the feedback resistor divider and is comprised of transistors (Q108, 107, 106, 105, 104 and driver transistor Q101). A silicon controlled rectifier (L), which is driven by the components of (A2) is designed to regulate the storage voltage across the series regulator. The circuit is such that regardless of the output load requirement, the power dissipation of the series transistor regulator is maintained within its rating.

3-10 The controlled rectifier driver senses the current through the pass transistor (A) as well as the voltage across the pass transistor to adjust the storage voltage of the pass transistor by controlling the average value of the voltage voltage across (AE-AB). The feedback circuit consists of (Q) and (M) and (N). (Q) is a measure of the load current, while (M) is a measure of the storage voltage, and the circuit is designed to limit the maximum dissipation in the series regulator. The voltage fed to the base of (Z) will be the divider voltage as indicated above. The voltage at the base of (Z) controls the current to the controlled rectifier board terminals 4 and 5. The current at terminals 4 and 5 determine the firing point of the controlled rectifier as explained below. Thus, a change in the voltage across the pass section triggers the silicon controlled rectifier in such a manner as to change the average voltage at (AE-AB) so that the power dissipation in the pass section is maintained at a safe operating level. The operation of the gating circuit on (A2) is accomplished in a novel way to achieve a wide range of firing control of the SCR gate. This control is from approximately 15° to 165° of each half cycle. The firing point is varied by setting the level of the base current of (Q2). The method of creating the firing pulse is by switching (Q4) on and off. This is accomplished with the following sequence of events; (C2) acts as the storage capacitor to set the bias levels for (Q1), (Q3) and (Q4). (Q1) conducts and charges (C1) when the emitter of (Q1) is more positive than the voltage at the base. The transformer winding and rectifier and the combination of (CR3) and (R1) allows the emitter to go positive at some point during the pulsating voltage. The current flow through (Q1) charges (C1). As (C1) discharges through (Q2), the base of (Q4) will be at the approximate negative voltage to switch (Q4) to the conducting stage. The (C1) discharge through (Q2) is controlled at the rate determined by the effective resistance presented to the discharge current. Therefore the full range of firing is controlled by the relatively small base current of (Q2). The switching on of (Q4) is controllable through almost all of the half cycle. The switching off is made rapid with the charge of (C3) establishing a voltage sufficient to switch off (Q4). The pulse thus established is transmitted to the controlled rectifier through pins 6 and 7 on (A2).

Output voltage control is achieved in the following manner. Suppose the Output Adjust (G) is varied to produce a reduced output voltage. Since the series regulator's response is much faster than the controlled rectifier, a momentary situation develops in which the series regulator voltage increases, i.e., the voltage (AE-AB) holds momentarily while the output voltage is reduced. As described above, when the series regulator voltage increases, the storage regulator amplifier loop causes the controlled rectifier output to restore the original series regulator voltage. In this case, the voltage at (AE-AB) drops to compensate for the output voltage reduction. It is thus seen that the controlled rectifier output (AE-AB) tends to "track" the output voltage, and in this manner maintains the series regulator dissipation within fixed limits.

3-11. The regulating principle through the series regulator feedback circuit is to maintain balance at the bases of (Q107 and Q108). These bases will maintain balance within a small voltage which is the error voltage due to feedback loop gain level. Due to the high gain of the system, the error voltage will be small and at maximum equal to the maximum allowable error of the equipment. The sequence of operation is by adjustment of (G), (Q108) base is unbalanced with respect to (Q107) base. The system will adjust itself up or down (depending on (G) increased or decreased) until the voltage level at both bases are equal. A load or line change will also unbalance the amplifier and require the same corrective action. One such action will be described. The other disturbances cause the circuit to react in a similar manner. If we wish to raise the output voltage, then the value is increased. This increase decreases the voltage at the base of (Q108). The error is amplified through the system and a signal is applied to the base of the pass transistor in such a manner to give up some of its storage voltage. The control rectifier raising its output average level. The rise in the output was such that the voltage at the output terminals divided by the value of (G) is equal to the zener voltage (CR111) divided (E) and (F).

3-12. The sensitivity and speed of response of the corrective feedback circuit is such that the above-described action occurs almost instantaneously, and the actual excursion of the load voltage is held to a very small value. The circuit is a true proportional regulator, and must allow a small but finite "error" to exist between the required and actual regulated voltage, so that this error, however small, can generate the correction signal. By proper circuit design, however, the error is held to a value which remains within the specified regulation allowance of the power supply.

3-13. When resistor (G) is readjusted to produce a different value of output voltage, the circuit makes a correction similar to that described above. Altering the resistance in the sensing voltage divider unbalances the input stage of the feedback amplifier, which then causes the circuit to produce a new value of voltage such that the drop across resistors (E-F) again equals the drop across diode (CR111). Reducing the value of resistor (G) for example, momentarily increases the drop across (E-F). However, this unbalanced condition at the amplifier input causes the DC output voltage to decrease until the drop across (E) and (F) again equals the drop across (CR111) and the circuit stabilizes at this new operating point, establishing a lower value of DC output voltage. See description of corresponding storage regulator action in paragraph 3-10.

3-14. Resistor (F) in the amplifier is provided to permit compensating for manufacturing tolerances in diode (CR111), its load resistor (H) and resistor (E). This resistor (F) is adjusted at the factory (and locked). If any of these components are replaced, check to see that full rated output voltage of the supply is obtainable at full load, with the voltage control at maximum clockwise position, with line voltage of 105 volts. If not, readjust (F) to provide full voltage under these conditions.

3-15 To use the Variable Current Adjust feature, set the front panel Current Adjust potentiometer to the current desired by means of calibration curve (Fig. A) or as follows: Load the Power Supply to the desired current at which limiting is required, then back off Current Adjust potentiometer until output voltage starts to fall off, rotate current adjust potentiometer a few degrees clockwise. Variable Current Adjust is accomplished by means of circuitry of (A3) and Current Adjust potentiometer (AF).

The overload current limit circuit operates in such a manner as to clamp the operation of the main voltage regulation feedback loop at the base of (Q104) under the condition of load current greater than the corresponding setting of CURRENT ADJUST (AF). The action of the circuit may be described as follows:

(AF) is a divider resistor whose voltage can be set anywhere between zero and -18 volts (the voltage levels of the negative output terminal and the lower end of zener diode (CR110) respectively), and this voltage is fed to the base of (Q302). The emitter of (Q302) is connected to the base of (Q101), the main series regulator driver transistor. The voltage level of this point varies with output load current developed across the emitter resistors of the series regulator transistors. Thus, when the load current attains a value high enough to cause the voltage at the emitter of (Q302) to drop below the preset base level, transistor (Q302) begins to conduct. This causes current flow through (R301) which then forces (Q301) to conduct. This action effectively clamps the base drive at (Q104) through diode (CR302). The action is quite sharp once conduction begins. Prior to conduction, the diode (CR302) effectively decouples the overload circuit from the main amplifier.

SECTION IV
MAINTENANCE

4-1. GENERAL. This section is arranged in the form of a trouble-shooting chart, with symptoms listed approximately in accordance with the frequency of occurrance. Possible causes for each, and their remedies, are listed in logical succession beginning with the most common, to facilitate rapid location and isolation of a defective element.

4-2. SPARE MODULES. Where practical, it is recommended that one or more spare printed circuit boards and regulator assemblies be kept available for use in maintenance. This will reduce down-time to a minimum and permit easy testing by direct substitution, making it possible to repair a defective module at some convenient time and avoid prolonged interruption of operation.

4-3. MALFUNCTIONS. The various ways in which DC power can deviate from normal operation are listed below. Each condition is treated separately in the charts that follow. Component symbol designations refer to the schematic diagram at the rear of the manual. Parts location are indicated in the parts layout photograph also included at the rear.

MALFUNCTION	TYPICAL MAGNITUDE
1. No output voltage at any control setting.	Zero or DC output voltage.
2. Low output voltage.	Maximum output voltage obtainable at no load is less than maximum rating.
3. High output voltage.	Minimum output voltage obtainable at no load is more than maximum rating.
4. Failure to regulate.	Output voltage drops 5% or more when load is applied, or varies ±2% or more under a ±10% variation in line voltage.
5. Poor regulation.	Regulation better than above, but not within specification.
6. Excessive ripple.	
A. With good regulation	RMS ripple exceeds specification, but regulation is within specification.
B. With poor regulation	RMS ripple exceeds specification, and regulation exceeds specification.
7. Instability	
A. Random large excursions	Output voltage "hops" intermittently by 5% or more, with constant load, and constant line voltage.

MALFUNCTION	TYPICAL MAGNITUDE
B. Gradual drift in one direction.	Output voltage changes by 1% or more per minute, after a 15-minute warmup,
C. Excessive drift under heavy load only.	Output voltage changes by 1% or more per minute, after a 15-minute warmup, but only after application of a heavy load.
8. Inadequate transient suppression.	Failure to "zero-lag". Upon sudden application of a full-load increase, output voltage dips sufficiently to cause a visible momentary deflection of the voltmeter needle.
9. Oscillation	
A. High frequency	Under constant load, output voltage is modulated by sawtooth or sine-wave with frequency of 200 cycles or more per second.
B. Low frequency	At constant load, output voltage exhibits relaxation modulation at or below 200 cycles per second.

4-4. NO OUTPUT VOLTAGE AT ANY CONTROL SETTING.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Pilot light (DS1) not lit.	1. No line power, or defective input connection.	1. Check power source, lines and connections.
	2. Input fuse (AG) blown.	2. Replace fuse. If fuse blows repeatedly, do not overfuse.
B. Repeated blowing of fuse (AG)	1. Shorted rectifiers (AA) or (L)	1. Replace.
	2. Shorted rectifiers on (A2, CR1 or CR2) or on (A1, CR101, CR102 CR103, CR104).	2. Replace.
C. Fuse (AG) blown.	1. External	1. Check for overload.
D. Unregulated DC across (AE) zero or low. Fuse (AG) not blown.	1. Open rectifiers (AA) or (L) (CR101, CR102 CR103, CR104, or on A2, CR1 or CR2)	1. Replace rectifiers or controlled rectifier,

NO OUTPUT VOLTAGE AT ANY CONTROL SETTING (cont'd)

SYMPTOM	POSSIBLE CAUSE	REMEDY
	2. Primary or secondary transformer open.	2. Replace transformer.
E. Unregulated DC present at (AE) but more than 15-25% higher than DC output.	1. Entire, or major part of unregulated DC voltage across (AE) absorbed by regulator transistors (A). Caused by short or excessive leakage between base of driver or regulator transistors (Q101) or (A) respectively and any positive voltage or ground. (For example: If positive output is operated at chassis ground and chassis.	1. Inspect for short. Isolate driver transistor from heat sink & chassis, and operate unit for brief interval. If this restores normal operation, replace driver insulation, and/or driver itself, as necessary. If not cleared, repeat for regulators (A).
	2. Amplifier or sensing circuit defective.	2. Check by momentarily shorting base to collector of (Q101). If DC output is restored, amplifier or sensing circuit is at fault. See end of this Section for amplifier check.
	3. Rate sensing capacitor (AH) shorted internally, or by external wiring short.	3. Inspect for short. Disconnect one terminal of capacitor. If DC output is restored, replace capacitor.
	4. Defective driver transistor.	4. Check by momentarily shorting base to collector on driver transistor at no load. Replace driver transistor.
	5. Ammeter (M1) open.	5. Check by momentarily shorting meter terminals. Replace.
	6. Resistors (P) all open.	6. Replace.

4-5 LOW OUTPUT VOLTAGE RELATIVE TO VOLTAGE ADJUST SETTING

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Unregulated DC present at (AE) in expected magnitude (15% to 30% higher than output voltage at nominal line voltage at no load)	1. Amplifier or sensing circuit defective.	1. Check by momentarily shorting base to collector of (Q101). If this restores DC output, check sensing voltage divider. See end of this Section for amplifier check.
	2. Rate sensing capacitor (AH) has excessive leakage.	2. Disconnect one terminal of capacitor. If this restores DC output, replace capacitor.

4-6 HIGH OUTPUT VOLTAGE

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Output voltage adjust knob has little or no control over DC output.	1. External sensing circuit improperly connected. Internal sensing voltage or wiring open.	1. With power off, check continuity of sensing leads, internal sensing circuit from positive output terminals to amplifier input and from negative output terminal to neutral bus of amplifier
B. Output control effective, Driver base (Q101) negative with respect to negative output terminal.	1. a. Bleeder resistor (AI) open, or regulator transistor (A) I_{CO} drain open resistor (AJ).	1. a. Check by applying full load. If this restores normal operation, check for open resistor or connection.
	b. Defective amplifier.	b. See amplifier check at end of this Section.
	c. Defective amplifier power supply.	c. Check voltage across filter capacitor (C102) (C103), or (AK) as shown on schematic diagram. If correct, check resistors (C-N) for open.

HIGH OUTPUT VOLTAGE (cont'd)

SYMPTOM	POSSIBLE CAUSE	REMEDY
		1. c. If incorrect, check the capacitors, (C102, C103), diodes (CR101 thru CR104) and secondary winding of transformers.
C. Driver base (Q101 positive with respect to negative output terminal.	1. Defective driver and/ or pass transistor.	1. Check for shorted transistors.

4-7. FAILURE TO REGULATE

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Load regulation is 5% or more, line regulation 2% or more.	1. a. Defective amplifier	1. a. See amplifier check at end of this Section.
	b. Defective amplifier power supply.	b. Check voltage values of filter capacitors (C103) (C102). If incorrect, check the capacitors, diodes (CR101 thru CR104) and main secondary winding of transformer. Check (D) and (C) for open.
	c. Very low performance transistor in regulator or driver circuit.	c. Check for equal voltages across resistors in series with emitters of power transistors, to detect defective transistor, check transistors in a transistor test set or by substitution.

4-8. POOR REGULATION

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Load regulation less than 5%, but not within specfications.	1. External sensing circuit incorrectly connected.	1. Check by operating unit with sensing terminals temporarily jumpered to the local output terminals. (Observe correct polarity).
	2. Low gain amplifier	2. See amplifier check at rear of this Section.
	3. Low beta in driver or power transistor.	3. Check by substitution or in transistor tester. Beta of 20 or more is acceptable.
	4. Oscillating amplifier	4. Check (AL) for proper value. See amplifier check at rear of this Section.

4-9. EXCESSIVE RIPPLE

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Output regulation is within specifications.	1. a. Circuit not bypassed to ground.	1. a. One output terminal of the supply should be connected to chassis ground whenever practical, either directly or thru a 0.1 mfd. capacitor of appropriate voltage rating.
	b. Filter capacitor (AE-B)-(C102) or (C103) open or of low value.	b. Replace.
	c. Note: Ripple at (AE) should not exceed 5%.	c. Replace.
	d. Rate-sensing capacitor (AH) open or of low value.	d. Replace.

4-9 EXCESSIVE RIPPLE (cont'd)

SYMPTOM	POSSIBLE CAUSE	REMEDY
	1. e. Hum pick-up in external sensing leads.	e. Check by operating unit with sensing terminals temporarily jumpered to local output terminals. Sheild or twist external sensing leads.
	f. Low-gain amplifier.	f. See amplifier check at end of this Section.
B. Output regulation poor.	1. a. Low beta in power transistor or driver transistor.	1. a. Check by substitution or in transistor test set. Beta of 20 or more is acceptable.
	b. Low gain amplifier	b. See amplifier check at end of this Section.
	c. Defective amplifier power supply.	c. Check diodes (CR101 thru CR104) for shorts or open capacitors (C102), (C103), for open, low value, or high leakage. Check diodes (CR110) (CR109) and resistors (C) and (D).

4-10. INSTABILITY.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Random large excursions of output voltage.	1. Intermittent failure of component or intermittent short or open in circuit.	1. Check primary power circuit by temporarily connecting base of driver transistor (A) to negative output terminals. If instability persists, check for intermittent breakdown in rectifiers (AA-L) or filter capacitors (AE-B).

INSTABILITY (cont'd)

SYMPTOM	POSSIBLE CAUSE	REMEDY
		1. Check for intermittent opens or shorts in unregulated DC circuit. Check driver and power transistors in tester, or by substitution. Check for intermittent opens or shorts or defective component from (AE) to output terminals. Look for intermittent open or short, of intermittently defective component in (1) amplifier, (2) amplifier power supply, or (3) sensing voltage divider and external sensing circuit. Check amplifier connector for poor contact. Check rate-sensing capacitor (AH). Check voltage across (CR109, CR110 and (CR111) for stability.
B. Gradual drift in one direction at any load, after 15-minute warmup.	2. a. Defective amplifier	2. a. See amplifier check at end of this Section.
	b. Drifting zeners.	b. Check (CR109), (CR110) and (CR-111). Replace if faulty.
	c. Output adjust potentiometer (G) unstable	c. Replace.

4-11. INADEQUATE TRANSIENT RESPONSE.

NOTE: This condtion should be checked by an oscilloscope at the output terminals of the supply, with the sensing terminals temporarily jumpered to the corresponding output terminals. None of the load current should be permitted to flow through any portion of the oscilloscope leads or the sensing leads.

4-11 INADEQUATE TRANSIENT RESPONSE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Regulation and ripple are within specification, and external sensing circuit is properly and firmly connected.	1. a. By-pass capacitor (B) open, or very low in value.	1. a. Replace.
	b. Filter capacitor (AE) low in value.	b. Replace.
	NOTE: A brief transient during switching is normal, The measurement of transient response may be complicated by inductive transients of 1 to 50 microseconds duration due to lead inductance, etc., but since these are easily handled by means of local by-passing, they have no significance in determination of the transient response of the supply.	

4-12. OSCILLATION.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Under constant load, output voltage varies at a cyclic rate (saw-tooth or sine wave) of 200 cycles or more per second.	1. a. Defective diodes (CR109) (CR110) or resistors (C-D).	1. a. Replace.
	b. By-pass capacitor (B)is open or of low value.	b. Replace.
	c. Rate sensing capacitor (AH) or its circuit is open.	c. Replace.
	d. Suppressor capacitor (AL) in amplifier is open or of low value.	d. Replace.
B. Under constant load, output voltage varies in "saw-tooth" manner at a frequency of 200 cycles or less.	2. a. Output capacitor (B) is open.	2. Replace.

4-12 OSCILLATION (cont'd)

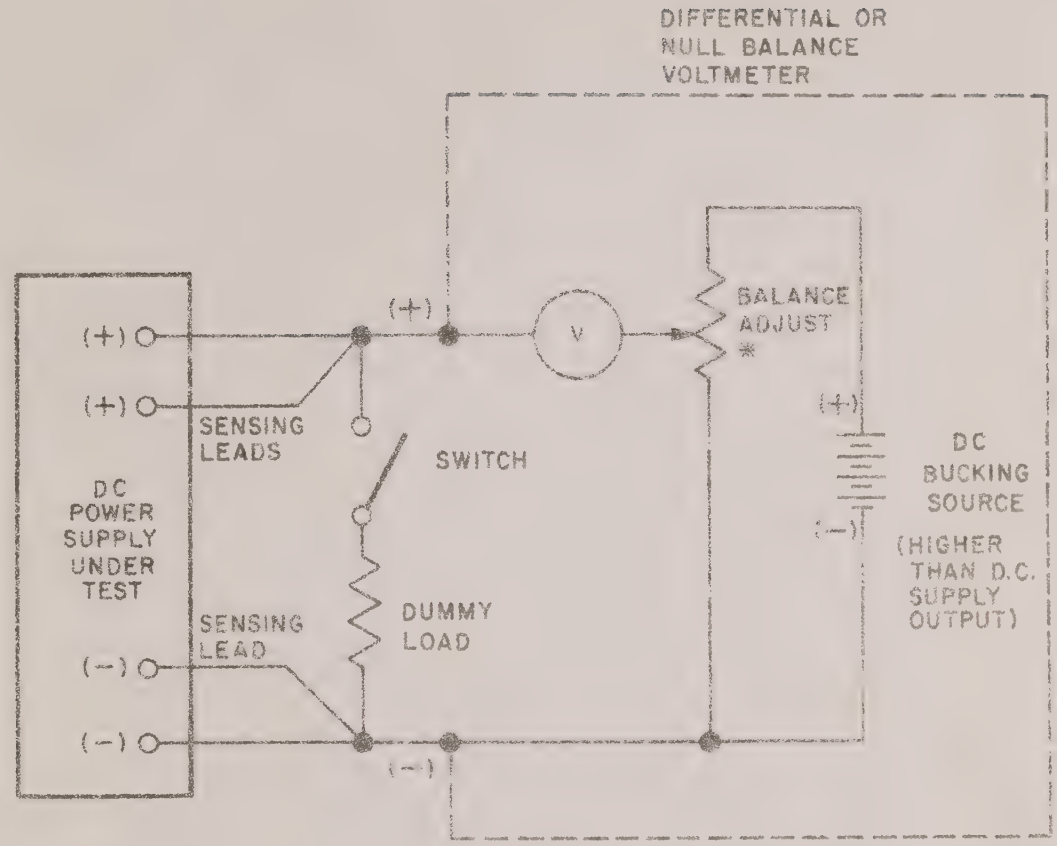
SYMPTOM	POSSIBLE CAUSE	REMEDY
	b. Rate sensing capacitor (AH) is open, or of low value.	b. Replace.
	c. Excessive capacitance in external load circuit.	c. If load contains capacitance equal to or greater than capacitor (B), special precautions are necessary. Check with NJE Corp. Engineering Department.
	d. Excessive amplifier gain.	d. If the beta(current gain) of one or more amplifier transistors is 150% or more of the manufacturer's bogie value, the increased gain which results (particularly at high ambient temperature) could result in this type of oscillation. Replacement of the transistor is required.

4-13. REGULATION CHECK. Because of the inherently slight regulation exhibited by this power supply, it is impractical to make a regulation check by observing a voltage measurement across the output terminals of the supply as the line or load is varied.

4-14. To accurately check the regulation, it is necessary to use an external source of DC voltage of approximately the same value as the power supply output, connected as shown in Figure 3. This DC bucking voltage can be either an electronic unit, null balance differerential voltmeter, or a group of batteries connected in series, furnishing a DC potential larger than the output voltage of the power supply under test.

The voltmeter should have a full-scale range of 0 to 5 or 10 volts (5-0. 5 with center zero, if available), since it will be used to measure only the difference between two almost equal voltages. The balance adjustment is used to bring the meter needle to approximately midscale before testing, so that the deviation above or below the normal output of the supply under test can be observed.

A10045



* RUN AS LITTLE CURRENT AS POSSIBLE THRU DIVIDER SO THAT BATTERY VOLTAGE DOES NOT DECAY.

PRECISE REGULATION CHECK

FIGURE 3

c. Stability Check. A detailed check for improper drift and intermittent failure can be made by utilizing a test rig similar to that shown for precise regulation check in Figure 3. The voltage across the zener diode reference source (CR111) is "bucked out", and monitored by a 0 to 1-volt (or smaller scale if available) high impedance DC voltmeter (null balance voltmeter). Drift or random instability will be readily visible in this test. Output voltages of the successive amplifier stages and regulating diodes (CR109) and (CR110) can then be monitored in the same manner. When checking a given amplifier stage by this method, the output of the previous stage should be shorted, to prevent external voltage variations from reaching the stage under test. When installing a new transistor in place of one shown to be defective, the stability check should be repeated, to make certain that the trouble has been eliminated.

MANUFACTURERS REPRESENTATIVES

Albuquerque, New Mex.

Barnhill Associates
319A Wyoming N.E., Albuquerque, New Mex.
265-7766

Boston, Mass.

Burlingame Associates, Ltd.
7 Wellington Street, Waltham, Mass.
TWinbrook 4-1955

Chicago, Ill.

Ridgway Associates
6100 W. North Ave., Chicago 39, Ill.
TUxedo 9-5715

Cleveland, Ohio

Ridgway Associates
5915 Schaaf Rd., Cleveland 31, Ohio
LAfayette 4-1421

Dallas, Texas

Carey-Wolf Co.
P.O. Box 12425, Ft. Worth, Tex.
TA 3-5383

Dayton, Ohio

Ridgway Associates
3898 Linden Ave., Dayton 29, Ohio
CLearwater 2-5604

Denver, Colo.

Barnhill Associates
1170 South Sheridan Blvd., Denver, Colorado
WEst 5-4645

Detroit, Mich.

Ridgway Associates
3384 Twelve Mile Rd., Berkley, Michigan
LIncoln 6-3312

Ft. Worth, Texas

Carey-Wolf Co.
P.O. Box 12425, Ft. Worth, Tex.
PE 8-1702

Houston, Texas

Carey-Wolf Co.
P.O. Box 14426, Houston, Tex.

Indianapolis, Ind.

Ridgway Associates
1224 N. Capitol Ave., Indianapolis 2, Indiana
MElrose 5-2401

Kansas City, Mo.

Lee Mark Associates
4021 W. 86th St., Prairie Village, Kansas
Niagara 2-3313

Los Angeles, Calif.

G. S. Marshall Company
2065 Huntington Drive, San Marino, Calif.
MUrray 1-3292

Montreal, Canada

Radionics, Ltd.
8230 Mayrand St., Montreal, Canada
REgent 9-5517

New York City Area

Burlingame Associates, Ltd.
510 South Fulton Ave., Mt. Vernon, N. Y.
MOunt Vernon 4-7530

Ontario, Canada

Radionics, Ltd.
4938 Yonge St., Willowdale, Ontario
222-3261

Philadelphia, Pa.

Burlingame Associates, Ltd.
222 Long Lane, Upper Darby, Pa.
JAckson 8-6080

Phoenix, Arizona

G. S. Marshall Company
30 Pima Plaza, Scottsdale, Ariz.
WHitney 6-5521

St. Louis, Mo.

Lee Mark Associates
2001 Big Bend Blvd., St. Louis 17, Mo.
Mission 7-1470

Salt Lake City, Utah

Barnhill Associates
300 So. Main, Centerville, Utah
AXtel 5-8521

San Diego, Calif.

G. S. Marshall Company
4410 Kearny Mesa Rd., San Diego, Calif.
BR 8-6350

San Francisco, Calif.

G. S. Marshall Company
801 Woodside Rd., Redwood City, Calif.
EMerson 6-8214

Seattle, Washington

Burt C. Porter Company
1209 Poplar Place, Seattle 44, Washington
EAst 3-8330

Syracuse, N. Y.

Burlingame Associates, Ltd.
514 University Bldg., Syracuse, N. Y.
GRanite 4-7409

Washington, D.C.

Burlingame Associates, Ltd.
8218 Wisconsin Ave., N.W., Washington 14, D.C.
OLiver 4-6400

Winston-Salem, N.C.

M. J. McDonald Co.
Whippoorwill Drive, Rt. 1, Pfafftown, N. C.
WAbash 4-2182

OUR WARRANTY: N J E Corp. warrants each power supply manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof, except tubes, semi-conductors and fuses. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and which upon our examination is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started. Written permission must be obtained from the factory, before a supply may be returned for examination.

NJE CORPORATION
Electronic Development & Manufacturing
Kenilworth, New Jersey • BRidge 2-6000
TELEFAX: FFP • TWX: CRANFORD 51